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THE ORIGIN OF LIMESTONE CAVERNS

By W. M. DAVIS

PROFESSOR OF GEOLOGY, EMERITUS, HARVARD UNIVERSITY

INTRODUCTION

CAVERNS in massive limestones are usually more or less filled with dripstones, and thus exhibit the work of two contrasted processes: excavation and replenishment. The first process, as generally understood in the United States, is taken to be the solutional work of percolating vadose water (water descending from the land surface to the water table) associated with the corrasional work of vadose or water-table streams. No adequate explanation for the change of process from excavation to replenishment is usually given with this explanation.

Another explanation of caverns was proposed by Grund in 1903.[1] He suggested that they are the solutional work of ground water below the water table during a lower stand of the cavern region; and that when the water filling is withdrawn in consequence of regional elevation, dripstone deposition begins.

I have attempted to work out the consequences of these two rival explanations, with special attention to their application in regions of level-bedded limestones; and then to confront the unlike consequences with facts of observation in the hope of determining which explanation works best. A fuller discussion of the problem is presented in the *Bulletin* of the Geological Society of America for 1930. The statement here given is assertive rather than argumentative.

CAVERNS EXCAVATED ABOVE THE WATER TABLE

The joints and bedding planes in a mass of recently uplifted, level-bedded limestones are here assumed to be close-fitting. Minute water ways will be opened along them, especially on lines of intersection, and a complex, angular, three-dimensional network of tube-

[1] Alfred Grund, "Die Karsthydrographie." *Penck's Geogr. Abhandl.*, 7, 103–200, 1903.

like crevices will be thus developed. At an early stage the crevices may be water-filled nearly to the land surface, because their narrowness makes water movement through them very slow; and during this stage it is ground water rather than vadose water which occupies them. But as subaerial valleys are deepened and as the lower paths of the sheet-like crevices are enlarged to linear passages, the water table will sink to the levels of near-by valley floors. All the crevices and passages above it will thereafter be occupied only by vadose water and ground air.

When the passage diameters reach or exceed those of a stove pipe or a barrel the passages may be called shafts and galleries. Then vadose streams, running with free surface on gallery floors and carrying some sediment from surface sinks, will corrade as well as dissolve the bed rock. The streams in the higher galleries will be segmented wherever new shafts are opened, and the further enlargement of such galleries will be much retarded. But at the same time the lowest galleries, nearly coincident with the water table, will be actively enlarged by their growing streams. A process of natural selection then becomes operative, by which the three-dimensional network of water passages, earlier opened at various levels, will be reduced to a two-dimensional branchwork at the lowest levels; and the branch-work galleries will then be worn down to grade with respect to the valley floors into which their streams discharge. The subterranean branch-work will resemble that of a subaerial stream system in having many small and slender twigs near its divides, where the amount of water available for their maintenance is small, and in the down-stream union of many twigs and branches in a trunk.

As this work advances the high-level galleries, little enlarged, may be nearly filled by deposition of calcite. Furthermore, solution in the lower galleries will probably be exceeded by corrasion; for the streams will cut downward until grade is reached, and laterally thereafter. At the same time solution will be lessened, because with the development of surface sinkholes the shafts at their bottom will so promptly receive most of the rain water that it will be little carbonated. Besides, solvent action by vadose trickles ceases when they become saturated, but corrasion continues as long as sediment-bearing streams run. It seems therefore that the part played by carbon dioxide in cavern excavation has generally been exaggerated.

When good-sized, low-level branching galleries are thus excavated, their floors should be worn down to even gradients; rock falls from roof and walls may cause local and temporary irregularities. But the walls and roof should not show marks of stream wear, because early-made marks of this kind would be removed by rock falls during gallery enlargement. The side walls may, however, show flutings formed by the solvent action of vadose trickles; but such flutings are subject to intermittent removal by rock falls.

During all these changes the branchwork pattern of the streams and their galleries will be more and more perfected. The general acceptance of this view is illustrated in the following passage by Meinzer regarding the underground drainage of limestone regions:

> Percolating water gradually dissolves and removes the limestone and thus produces large underground channels [galleries]. By this process a system of underground drainage may be developed which is comparable to a surface drainage system in another [non-soluble] terrain. The underground streams, like the surface streams, become adjusted to some base level, such as the sea, a lake, or a major surface stream, into which they discharge, and they tend to become graded to this base level by the laws of stream gradation.[2]

In the meantime the general down-wear of the land surface, especially on the slopes of growing sinkholes, will convert the originally even upland into a mature or karst surface of deep hollows separated by sharp edges, peculiar to limestone regions. Then as such down-wear continues and the karst forms are subdued, the ever-enlarging, low-level galleries will be locally converted into open or blind valleys by the collapse of their roofs and the gradation of their walls. Eventually all the roofs will be removed, all the walls will be worn down, all traces of the caverns will vanish and a nearly featureless peneplain will result.

The opportunity for dripstone development offered by the main galleries of such caverns is not good, even at their maturity, because their ground air is moistened by the streams. It should be noted that, under this explanation of caverns in level limestones, their excavation is the work of only one cycle of erosion; indeed, of only the youthful and mature stages of one cycle, for during the older stages the previously excavated caverns are destroyed. Caverns thus formed are therefore at their best during the karst stage. However, if a limestone region in that stage of its cycle suffers regional elevation, in consequence of which new branchwork caverns are developed at a lower level than before, the first-formed, upper caverns will be deserted by their streams, and dripstone deposition will then, as Weller has shown,[3] go on apace before the upper caverns are unroofed by general surface degradation.

[2] O. E. Meinzer, "Relations of Ground Water Conditions to Leakage of Reservoirs." *Am. Inst. Min. Engrs. Tech. Pub.*, 215, 1929.

[3] J. M. Weller, "The Geology of Edmondson County . . . [Kentucky]." *Ky. Geol. Surv.*, 1927.

CAVERNS EXCAVATED BELOW THE WATER TABLE

Following King's results[4] it would seem that, at an early stage in a cycle of erosion, ground water may make a deep descent beneath uplands before its ascent toward discharging springs in valley floors is begun. But when maturity is reached in a limestone region, much underground water may flow as water-table streams without making so great a descent. Yet even then some of it must circulate slowly at greater depths. This is assured by the depth at which water is encountered in deep wells. For example, Bain mentions[5] a well 1,750 feet deep in a valley that is 750 feet below the adjacent limestone uplands in southern Missouri, and infers a circulation to a depth of 2,500 feet beneath the uplands. It is the solvent action of this deep and slow moving ground water that is now to be examined.

As with vadose water the movement of ground water must be at first chiefly along intersections of joints with each other and with bedding planes. A complex, angular, three-dimensional network of fine crevices will therefore be developed in this case also, but more slowly than by vadose water, because deep-lying ground water is almost stationary; also because deep-descending water will be partly charged with calcite at the beginning of its descent. The fine crevices will, however, be gradually widened into shafts and galleries, all of which must remain water-filled, to whatever size they grow. Unlike the high-level crevices and passages in the network above the water table, none of the low-lying crevices below the water table will be deserted, however small they are, by the withdrawal of water to lower and larger ones. All will continue to grow. Hence the three-dimensional network will here be preserved, instead of being converted into a two-dimensional branchwork. But like the vadose branchwork, the ground-water network should be of smaller dimensions near the divides and should increase in size toward the main valleys. Yet unlike the vadose branchwork, gallery floors here will not be graded; they may ascend and descend somewhat irregularly.

Narrow and deep galleries may be dissolved out along master joints, but their angular turns from one joint to another need not be rounded off, as they should be if similar joints are followed by vadose streams at higher levels. Broad and low galleries may be dissolved out on especially soluble layers; and several such galleries may be developed simultaneously at different levels. Their breadth will be determined largely by the strength of their roof. Rock falls from roof and walls may take place as galleries are enlarged; hence both roof and walls may have forms of two kinds: forms of solution, whatever such forms may be, and forms of fracture. The fallen blocks will be gradually dissolved away, and the first-fallen, lower members of a slowly growing heap should be most rounded by this process. In large galleries the later fallen blocks should rest on a floor of clay, the insoluble residue of the dissolved limestone; and when such a floor cover is well developed, further enlargement of the gallery should be only upward and laterally. No dripstones can be formed while the water-filling is present; but if the solvent power of a saturated water-filling is diminished by any cause, crystals of calcite may be deposited on the walls, thus making the cavern resemble an immense geode.

The time factor is here of great importance. The excavation of deep-lying caverns in a limestone region by ground-water solution may continue during an entire cycle of erosion, during which so much of the upheaved limestones as stand above peneplain level will pass through all the changes of surface and cavern forms described above, until peneplanation is reached. As calcite is soluble in about 70,000 times its volume of non-carbonated water, the increasing volume of ground water in a growing cavern must be changed many thousand times during the cavern growth. But as the duration of a cycle of erosion may well be several million years, the time available for these changes in a cavern beneath a peneplain is enormously long. At least several months may be allowed for the supply and withdrawal of the water in crevices an inch in width, and in passages of knitting-needle or stove-pipe size during early stages of growth; and one or more centuries in great galleries at late stages of growth. Such periods of time would seem long enough for the ground water to become saturated. In the tomb-like stillness of large galleries, solution in slow-moving water may be aided by diffusion and also by a slow convection, due to the sinking of saturated water in contact with roof and walls and its replacement by less saturated water from below. Moreover the quick descent of rain water down sinkhole shafts during maturity will be changed in the later stages of a cycle, when the land surface is subdued to low relief or worn down to a peneplain, to a slow percolation through the residual soils, and the descending water will then have a good chance of becoming carbonated. Furthermore, the water table then lies so little below the surface that the descending water need not have become saturated when it reaches that level, and will therefore continue its solvent action at lower levels. On the other hand small differences of head beneath a peneplain will retard ground-water circulation and thus lessen its solvent power; but with increasing size of shafts and

[4] F. H. King, "Movement of Ground Water." *Nineteenth Ann. Rep. U. S. Geol. Surv.*, 1899, Pt. 2, 59–294.

[5] H. F. Bain, "Lead and Zinc Deposits of the Ozark Region [Missouri]." *22nd Ann. Rep. U. S. Geol. Surv.*, Pt. 2, 23–227, 1901.

galleries a given head will cause a less sluggish circulation.

In case some of the ground water, coming from deep sources, is more or less charged with carbon dioxide, as Emmons has suggested in his study of ore-filled cavities in the limestones of the Mississippi Valley,[6] the rate of cavern excavation would be accelerated; and in such cases, the escape of some of the carbon dioxide in consequence of diminution of pressure with ascent might provoke deposition of calcite crystals on the cavern walls, as has been noted.

The withdrawal of the water-filling from ground-water caverns may be brought about in two ways. During the later stages of an erosion cycle, especially in a region several hundred miles inland from its river mouths, the slow continuance of degradation must lower the valley floors to fainter and fainter gradients, and the associated water table will then also be lowered, so that caverns which were previously below it will now be left above it, and their water-filling will thereupon be discharged. But the same result is more efficiently brought about by regional elevation, as Grund pointed out. If this takes place after peneplanation the old rivers, rejuvenated, will during and after the elevatory movement erode new valleys, and the caverns that are tributary to such valleys will be drained. It is quite possible that some caverns may then have roofs so thin that they will collapse when the water, which aided in sustaining it then, is drained away. Such caverns will soon assume the form of valleys, open or blind. They should not be expected near the peneplain divides.

As soon as ground-water caverns thus come to be occupied by ground air, their replenishment with dripstones may begin, except in the lowest galleries where the ground air is dampened by streams. At the same time the streams will attempt to convert any network in their courses into a branchwork; but as this attempt is not made until the cavern galleries are of good size, it will have little or no effect on them, especially on the higher galleries, in which the network will therefore survive.

Facts to be Accounted For

All our greater caverns are in uplifted and more or less dissected peneplains. Under the theory of excavation by vadose water, these caverns must have been excavated and their dripstones deposited within them since the upheaval of their regions. Under the theory of excavation by ground water, they should have been produced before the elevation of their region, during the previous cycle of peneplanation, and only subordinately modified, chiefly by dripstone deposition, since their elevation.

All our larger caverns have galleries of a pronouncedly network pattern. This is wholly inconsistent with the requirements of the current theory of vadose excavation, but perfectly consistent with the alternative theory of ground-water excavation. And if great network caverns have been thus excavated, smaller caverns of simpler pattern may have been similarly excavated.

Three caverns in a much degraded part of southern Indiana, with some network loops in their galleries as described by Malott,[7] appear to illustrate successive stages in the withdrawal of a former water-filling as a result of slow valley deepening, independent of regional elevation.

Some linear caverns in the same state, described by Malott[8] and by Addington,[9] exhibit angular turns, suggestive of quiet, immature solution by ground water on intersecting joint planes, rather than of stream corrasion.

The walls and roofs of certain caverns exhibit peculiar rock forms that are much more suggestive of solution than of corrasion.

A few caverns are known in which the walls are studded with calcite crystals, some of which are over a yard in length. One of these caverns in Missouri[10] and another in Arizona[11] were water-filled when first found, but they have been emptied by pumping in the course of mining operations. A third in the Black Hills had been naturally drained; its crystals are described as in part covered by dripstones.[12]

The floors of cavern galleries are by no means always graded. The broad floor of a large gallery in Carlsbad cavern, New Mexico, has a pronounced slope.[13]

As far as these varied facts go, they discredit the theory of excavation by vadose water and give good support to that of ground-water excavation. But it is still eminently possible that certain caverns of simple pattern are of vadose-water origin.

Caverns in Inclined Limestones

Several important caverns in the inclined limestones of the Appalachians have, as described by Hovey[14]

[6] W. H. Emmons, "Sulphide Ores in the Mississippi Valley." *Econ. Geol.*, 24, 221–271, 1927.

[7] C. A. Malott, "Three Cavern Pictures." Proc. Ind. Acad. Sci., 38, 201–206, 1929.

[8] C. A. Malott, "Physiography of Indiana," in "Handbook of Indiana Geology." Ind. Dept. Conserv., p. 236, 1922.

[9] A. R. Addington, "Special Topographic Features . . . Bloomington, Indiana, Quadrangle." Proc. Ind. Acad. Sci., 38, 247–261, 1929.

[10] Arthur Winslow, "Lead and Zinc Deposits." *Mo. Geol. Surv.*, 7, 566, 1894; also, Bain, as above, 109, 110.

[11] J. B. Tenney, personal communication.

[12] E. O. Hovey, "Crystal Cave of South Dakota." *Sci. Amer. Suppl.*, 57, 23657–23658, 1904.

[13] This statement is based on a detailed topographic map made for the National Geographic Society by R. H. Runyan on a scale of 50 feet to an inch, with 5-foot contours on the gallery floors.

[14] H. C. Hovey, "Celebrated American Caverns." Cincinnati, 1882. 2nd. ed, 1896.

and by Reeds,[15] well-developed gallery networks, highly suggestive of excavation by ground-water solution; but they possess also one or more well-defined levels, independent of their bedding planes, and suggestive of control by water-table streams during pauses in regional elevation. How these levels are to be explained, and whether they have been determined by thrust planes I can not say.

Observational Study of Caverns

It is desirable that caverns should be studied with especial attention to the detailed form of their rock walls and to the general pattern of their galleries. During such study the attempt should be made to explain every element of their form by each one of the afore-discussed theories. Care should be taken not to be distracted from the primary study of cavern excavation by the secondary fascinations of dripstone replenishment. Each of the two theories should be impartially considered in its relation to the physiographic evolution of the cavern district, and a provisional place should be found under each theory for every cavern feature, large and small. Thus in time a good theory of limestone caverns may be established.

EDGAR FAHS SMITH: PROVOST, CHEMIST, FRIEND

By CHARLES FRANKLIN THWING

PRESIDENT EMERITUS OF WESTERN RESERVE UNIVERSITY

Often have I wished I might make a book seeking to interpret the most loved teachers of our colleges. What a rich treasury it would indeed be of dear souls loving and loved. In it I would tell of "Old Peabo" of Harvard, who embodied the great phrases of Paul's eulogy on charity. Included, too, would be Shaler, also of Harvard, of whom it was said, "Late in life he was fond of telling the story of his once having overheard two students talking together. 'Where's the old man?' asked one. 'Hush!' said the other, 'if he hears you call him old man, he'll walk your d—d legs off.'"[1] Chief among the worthies would be North of Hamilton, whose other and more affectionate name was "Old Greek." Of him a graduate wrote, "Professor North, I love you because you inspired in me a desire to do my best and to realize in my life what God has made possible."[2] Of course, too, a place would be had for Garman of Amherst. Of Garman Principal Stearns of Andover has written:

> To him hundreds of Amherst men owe the best inspiration of their lives. Those who have enjoyed the privilege of sitting as disciples at his feet realize as none others can what a rare privilege has been theirs. He taught us the beauty of truth. Through him the spiritual world was brought near and its glory revealed. He made us feel the presence of the Divine within us, and he stirred as few men have been able to do within the hearts of his pupils the desire to serve. The wonderful influence he exerted over the minds and lives of his students was unique in the educational world. Sluggish minds were stimulated to activity; careless minds were taught the value of accuracy; indifference was changed to eager desire. To many an Amherst man the most sacred and cherished memory of college days will always be that morning hour in Walker Hall where intellect was quickened and ambition aroused.[3]

The interpreter also would not leave out Wright of Middlebury, who held higher hope for his students than they had for themselves. One of these students wrote to him saying, "I am trying to catch up with your ideals for me." In the list I should want to include from a wholly different zone Osler, the teacher of medical students in three universities, Jowett of Baliol, and Tholuck of Halle, a theologian gifted with wit and humor, and with paternal love for his students.

Yet as noble, as inspiring, as formative, as loved, and as loving as any other of the noble group is Edgar Fahs Smith. Of the fourteen provosts in the university I have known four: Pepper, the refounder, the inspiring teacher; Harrison, the watchful and insistent financier; Penniman, the present head, the faithful conservator and the broad-minded administrator; and Smith, whom Penniman succeeded, and of whom I now write in a way most personal.

On the campus of the University of Pennsylvania, within sight of a laboratory which he planned and in which he worked, stands a statue bearing this inscription:

[15] C. A. Reeds, "The Endless Caverns of the Shenandoah Valley" [Virginia]. New York, 1925.

[1] "The Autobiography of Nathaniel Southgate Shaler," p. 369.

[2] S. N. D. North, "Old Greek. A Memoir of Edward North with Selections from his Lectures," p. 138.

[3] Eliza Miner Garman, "Letters, Lectures and Addresses of Charles Edward Garman," p. 581.

EDGAR FAHS SMITH
Provost 1911–1920
Teacher Inventor Friend

The four words represent the four-square relation of his life. Each word, illuminating, represents either the service he gave, or the contribution he made, or the relations he held. I can not but believe, however, that the last word, Friend, is the more and most important.

The nine years of his provostship were perhaps the most trying of all the decades of his life. He accepted the great office and undertook its duties under the earnest persuasiveness of the board of trustees. He was reluctant to give up his daily and double work of teaching and of research. Technically, during his administrative period, he continued his professorship. The opportunities of the professorship were his life. He, however, accepted the provostship under the promise, as he understood, that he should have no responsibility for the financial relationships of the university. Especially did he insist that he should be free from any specific or implied duty of raising funds either for endowment or for meeting current expenses. For such undertakings his immediate predecessor, Harrison, had peculiar power. Hardly, however, had he been placed in the provostship when it became plain that the trustees were relying on him for important financial duties. He once said to me, with tears in his voice, "It almost killed me." Possibly one might soberly say that the financial condition became a cause which ultimately contributed to his early death.

Of course one might add that Smith should have known! For he is not the first of college presidents who has learned that honest and high-purposing boards of college trustees allow themselves to give happy promises of immunity from specific labors in financial administration to a newly elected president, promises which it seems later so easy to forget or to neglect.

Yet it is as teacher, as investigator and as friend that, as declares the monument, the personality is most beautiful and preeminent. This trinity of great forces and qualities are wonderfully joined together in a noble unity of personality. Edgar Smith's service as teacher opened the door to friendships, and the friendships ministered unto his work as a teacher. His teaching, too, was constantly reinforced by his researches, and his teaching contributed certain human impulses unto his investigations. His work was indeed a unity, as his personality was a unit. Too many teachers make their teaching and their personality independent parts of their one character. Such divisions or subdivisions are, or at least should be, impossible.

But to these three constructive elements are to be added—and the addition could have fittingly been written on his monument—his service as a writer. For his books, biographical and theoretical, were the normal expression of the studies of the laboratory and of the library. Their number is indeed colossal, and their variety nothing less than immense.

This is not the place to give in detail the contributions which he made, through writing and research, to chemistry organic, inorganic, analytical, electro and historical. To name even the investigations, the experiments, the discoveries, would bear both the writer and the reader too far afield. Perhaps the most important contributions were those devoted to electrochemistry,

> . . . a domain in which he was a pioneer and soon became a recognized leader of international reputation. In the hands of this master craftsman, the electric current became a tool of undreamed usefulness and possibilities, opening up wholly new methods of analysis, separation and determination. About half of all the research papers he published were based upon new applications of the electric current. His introduction of the rotating anode together with the employment of currents of high amperage and high voltage marked a new epoch in the development of electroanalysis. His books on electrochemistry quickly became and have since remained the standard texts in this country, while the Harrison Laboratory was soon known throughout the world for its leadership in this branch of chemistry.[4]

His biographies of chemists, too, numbered more than a score, and his interpretations of chemistry historical and theoretical almost an equal number.[5]

To the scholar even, and to one who is not a scholar,

[4] SCIENCE, May 31, 1929, p. 560.

[5] Separate books, brochures or articles have been published by him concerning the following chemists: Theodore G. Wormley, Jr. (1897); Robert Empie Rogers (1905); George F. Barker (1907); Fairman Rogers (1909); Robert Hare, an American chemist (1917); James Woodhouse (1918); James Cutbush (1919); Franklin Bache (1922); James Curtis Booth (1922); Samuel Latham Mitchill (1922); Charles Baskerville (1923); Martin Hans Boye (1924); John Griscom (1925); James Blythe Rogers (1927); Priestley in America (1920); Priestleyana (1922) and the Priestley Medal Lecture (1926). More general treatises, written wholly or largely from the historical point of view, were: "Chemistry in America" (1914), "Men of Science from the Keystone State" (1914), "Chemistry in Old Philadelphia" (1918), "The American Spirit in Chemistry" (1919), "Progress of Chemistry" (1921), "Our Science" (1922), "A Half Century of Mineral Chemistry in America, 1876–1926" (1926); "Observations on Teaching the History of Chemistry" (1926), "Early Science in Philadelphia" (1926), "Fragments Relating to the History of Chemistry in America" (1926), "A Look Backward" (1927), "A Glance at the Early Organic Chemistry of America" (1927) and "Old Chemistries" (1927). SCIENCE, May 31, 1929, p. 564.

it is inevitable that the thought and heart turn to Smith as a friend. For as a friend I knew and loved him. As an adopted son of the University of Pennsylvania I join with tens of thousands of the real sons of Alma Mater in declaring that he was chief among our dearest. Toward him one has the feeling which an American soldier declared in saying that he went to France for flag and for country, but that he went over the top for mother. For Smith helped his students to carry chemistry into life. Its methods were life's methods, its principles life's principles, its prophecies, its rewards prophetic of life's happiness. To his students he was at once a father and an elder brother. Their sorrows were his sorrows, their triumphs his triumphs, their achievements gave to him a sense of glory, with their slowness of advance or their rapid progress he sympathized, and in the rapidity and height of their advancements he rejoiced. His simplicity, his altruism, his sense of reality, his sturdy honesty, the depth of his thoughtfulness, the breadth of his tolerance, his vision of ideals, inspired, quickened, moved his students. His devotion to them was structural and formative in manhood. He was their friend. He wrote, as a last sentence to his interpretation of Wetherill, "He was one of those Golden Natures who help us form Ideals of Life." The sentence itself we have a right to think of as autobiographic.

OBITUARY

MEMORIALS

THE Edgar Fahs Smith Memorial Collection in the History of Chemistry, which was presented to the University of Pennsylvania two years ago, has been endowed by Mrs. Edgar F. Smith. The collection has been placed in the Harrison Laboratory of Chemistry, and comprises rare books in chemistry, portrait prints and engravings, manuscripts and autograph letters. A catalogue is in course of preparation and will shortly be available for distribution. Miss Eva V. Armstrong, who was formerly Dr. Smith's secretary, has been appointed curator.

A PORTRAIT of Dr. William Stewart Halsted, until his death in 1922 professor of surgery in the Johns Hopkins University, painted by Mr. Casilear Cole, has been presented by Dr. Halsted's family to the Duke University School of Medicine and Hospital. One of the surgical wards of the Duke Hospital is named Halsted Hall.

A BUST of Carl Friedrich Gauss, the distinguished mathematician and physicist, has been placed in the Massachusetts Institute of Technology in memory of his great-grandson, Carl Friedrich Gauss, an alumnus of the institute in the class of 1900. The bust, originally sent by the German Government to the Chicago World's Fair in 1893, was recently presented to the institute by the mother, sister and brother of the late Mr. Gauss.

A TRUST fund for botanical research has been established at the University of Minnesota as the result of a request made by the late Dr. J. Arthur Harris a year ago on his death-bed. He asked that nothing be spent on flowers for his funeral, but that the money be put into a trust fund for research in botany. The fund, contributed by university staff members and others, now amounts to $1,066. Dr. Harris was head of the department of botany of the University of Minnesota and was also connected with the Agricultural Experiment Station. He was an authority on biometrics, and one of the four authors of "The Measurement of Man," a study in that field adopted by the Scientific Book Club last summer.

RECENT DEATHS

DR. JOHN HENRY COMSTOCK, emeritus professor of entomology at Cornell University, died at Ithaca on March 20, after a prolonged illness. He was eighty-two years old. Mrs. Comstock, also professor emeritus at Cornell University, died last year.

CAPTAIN HENRY MARTYN PAUL, assistant astronomer at the Naval Observatory from 1875 to 1880 and from 1883 to 1897, professor of mathematics in the U. S. Navy from 1897 to 1913, died on March 15, at the age of eighty years.

DR. EDWARD VERNON HOWELL, founder of the School of Pharmacy of the University of North Carolina, and dean for thirty-three years, died on February 14, at the age of fifty-nine years.

FRANK M. DORSEY, formerly chief of the development division, Chemical Warfare Service, died on February 10, at the age of fifty-two years.

THE death is announced at the age of forty-six years of Dr. Paul Trendelenburg, professor of pharmacology and director of the Berlin Pharmacologic Institute.

PROFESSOR ENRICO SERENI, head of the department of physiology at the Naples Zoological Station, died suddenly on March 1. He was thirty-one years old.

Nature reports the death of Mr. J. D. H. Dickson, senior fellow of Peterhouse and author of numerous papers on thermodynamics and thermoelectricity, on February 6, aged eighty-one years; of Mr. D. T. Jones, chairman of the Fishery Board for Scotland, on February 4, aged sixty-five years, and of Dr. Albert Schamelhout, secretary of the International Pharmaceutical Federation, on January 20, aged sixty years.

SCIENTIFIC EVENTS

AN AGRICULTURAL RESEARCH INSTITUTE FOR PORTO RICO

A NEWS bulletin of Science Service calls attention to the circumstance that President Hoover's visit to Porto Rico may revive interest in the establishment of a graduate school of tropical agriculture on the island, a project in which Governor Theodore Roosevelt is greatly interested. Pointing to the achievements of the school of tropical medicine which was established on the island in cooperation with Columbia University, Governor Roosevelt states his belief that Porto Rico is peculiarly fitted to become a great center for Pan-American research and learning.

Cornell University, in whose school of agriculture many Porto Rican boys have studied, is particularly interested in the proposed graduate tropic-agricultural school, and is expected to cooperate in its founding and maintenance. The National Research Council some years ago recommended such an institution. Subsequently members of the committee of biology and agriculture of the council visited Porto Rico and unanimously decided that it would be the logical place to establish such a school.

There is at present a good department of agriculture in the University of Porto Rico, graduates of which are more and more in demand in South American countries for special consultant and advisory work.

In 1926, Commissioner Carlos E. Chardon went to Colombia to make a survey for the agricultural school at Medellin, and, following the publication of his report, Colombia asked three graduates of the Porto Rico University to come there as teachers. Later an agricultural experiment station was built and equipped in the Department of Valle del Cauca in Colombia under Porto Rican guidance, and two former directors of the Porto Rican Agricultural Experiment Station were offered good consultant positions with sugar companies in Cuba, Santo Domingo and Peru.

Another result of the agricultural expedition to the Cauca Valley was a large collection of parasitic flora and the publication of a pamphlet called "Mycological Explorations of Colombia," which is in great demand among botanists.

Last year Ecuador sent its director of agriculture, Dr. Abelardo Pachano, a Cornell graduate, to Porto Rico to study agricultural research and experimentation. Dr. Pachano took two Porto Rican university agricultural graduates back with him to Ecuador. Venezuela, Panama and Peru have also offered positions to Porto Rican specialists in agriculture.

Because of the Spanish culture, language and tradition in the lives of Porto Ricans, Governor Roosevelt holds that the islanders are admirably adapted to act as intermediaries between the United States and South American countries on diplomatic missions. A still firmer basis of international understanding can be brought about, he believes, through help such as Porto Ricans now are rendering to South American countries along scientific lines.

For that reason, Governor Roosevelt hopes that the graduate tropic agricultural school on the island sponsored by Cornell University may soon become a reality. Soil possibilities of many of these south and central American countries are so varied that the day may well come when a wide variety of northern fruits and vegetables will be produced for home consumption in the tropics, as well as coffee, tobacco, pineapples and other tropical foods for export.

VIRGIN FOREST LANDS OF THE UNITED STATES

THE area of virgin forest lands in territory now within continental boundaries of the United States was approximately 800,000,000 acres at the time Columbus came to America and is now less than 100,000,000 acres, according to estimates made available on March 10 by the Forest Service and summarized in the *U. S. Daily*.

By far the greater portion of the decrease is attributable to clearings made to provide acreage for farms, particularly in the eastern section of the country. The area cleared to make way for agricultural operations since the beginning of the twentieth century is comparatively small, it was pointed out.

The estimates represent results of efforts to obtain the closest possible approximations in the face of absence of conclusive data, it was emphasized.

The total area of forest land in the United States, exclusive of Alaska, reached by forest fires in 1929 was 46,230,120 acres. Of this total 4,876,320 acres were located in protected areas while 4,353,800 acres on which fires occurred were not within sections over which organization for protection against fire has been established. The total amount of forest lands needing protection against fire is estimated by the Forest Service at 589,809,240 acres. Approximately two thirds of this acreage is protected.

A compilation made in 1923, showing little need for revision in later years, placed the amount of timber affected by the presence of insects at 9,000,000,000 board feet. This estimate includes not only the trees killed by bark beetles and defoliating in-

sects but also timber damage caused by borers and other insects which caused reduced timber values, affected chances of forest reproduction and impeded the growth of trees. A large amount of timber damaged by insects lends itself to salvaging operations.

The annual loss by decay has been estimated to be 300,000,000,000 board feet. Timber losses caused by erosion of soil are small, since the presence of tree stands are a protection against erosion, except in small areas, such as the banks of streams.

Although timber is being cut from some land to permit extension of farm areas, the amount of land formerly used for farming and allowed to revert to classification as "forest land" is larger. Any losses of timber resources that otherwise might take place are thus offset.

The Forest Service is now making a survey of forests in the United States which will require several years for completion. Survey work already has advanced in the Pacific Northwest region and in some other sections.

THE FIELD MUSEUM OF NATURAL HISTORY

THE annual report of Mr. Stephen C. Simms, the director of the Field Museum of Natural History, a book of 256 pages with twenty photogravure illustrations, has been issued. The museum was the recipient of a number of noteworthy benefactions during the year. Gifts received for various purposes include $154,547 from Mr. Stanley Field, president of the institution; and $166,000 from Mr. Marshall Field, of New York, a trustee.

After allocation of all contributions, and all income from the museum's endowments and other sources, the museum ended the year with an unprovided for operating deficit of $114,898. Total expenditures for the year, including general operating expenses, purchases of collections, cost of expeditions (excluding those privately financed for the museum by various sponsors), equipment, the N. W. Harris Public School Extension of the Museum, and the James Nelson and Anna Louise Raymond Foundation for Public School and Children's Lectures, amounted to $920,110. Mr. George A. Richardson was elected a trustee to fill the vacancy on the board caused by the death of Chauncey Keep.

Mr. Simms reports that the museum received 1,322,799 visitors during the year, and in addition, outside activities conducted by its units known as the N. W. Harris Public School Extension, and the James Nelson and Anna Louise Raymond Foundation, reached approximately 716,000 children in the schools, at camps, community centers and elsewhere.

The report gives detailed accounts of the work of seventeen expeditions which the museum had in operation both in this country and in distant parts of the world during 1930. Most important of these were the Vernay-Lang Kalahari Expedition, the Field Museum Archeological Expedition to the Southwest (financed from a fund established by Julius Rosenwald and the late Augusta N. Rosenwald), the two Chancellor-Stuart-Field Museum Expeditions to the South Pacific and to Aitutaki (Cook Islands), an expedition to Africa sponsored and led by Captain Harold A. White, of New York, and Major John Coats, of London; an expedition to India sponsored and led by C. Suydam Cutting, the Field Museum-Oxford University Joint Expedition to Kish, Mesopotamia, the Frederick H. Rawson-Field Museum Ethnological Expedition to West Africa and the Marshall Field Botanical Expedition to the Amazon.

A new exhibition hall devoted to marine mammals was opened, and throughout the museum a large number of new exhibits illustrating anthropological, botanical, geological and zoological subjects were installed. Work was begun on preparation of two new halls which will be devoted to comprehensive exhibits relating to prehistoric man and to physical anthropology. Hundreds of gifts of material for addition to exhibits and study collections were received from donors located in all parts of the United States and many foreign countries.

THE AMERICAN PHILOSOPHICAL SOCIETY

THE American Philosophical Society, Philadelphia, will hold its annual meeting on April 23, 24 and 25. The president, Dr. Francis X. Dercum, and the vice-president, Dr. Henry Norris Russell, of Princeton University, will preside over the session. Dr. Russell will give the evening lecture on "The Chemistry of the Stars." The annual dinner will be given at the Bellevue-Stratford Hotel on Saturday evening. A large number of papers will be presented on the opening day and a symposium has been arranged on "The Changing World," which is as follows:

SECTION I. TENDENCIES IN THE NATURAL SCIENCES

"The Astronomer's Goal": Frank Schlesinger, director of the Yale University Observatory.

"The Assault on Atoms and Molecules": Arthur H. Compton, professor of physics, University of Chicago.

"Hopes in the Biological Sciences": William Morton Wheeler, professor of entomology and dean of the Bussey Institution for Research in Applied Biology, Harvard University.

"Lengthening the Span of Life": Lee K. Frankel, second vice-president of the Metropolitan Life Insurance Company. (Introduced by Dr. Huebner.)

"Technology and Material Progress": Dr. Willis R. Whitney, director of the Research Laboratory of the General Electric Company, Schenectady. (Introduced by Dr. Rice.)

SECTION II. TENDENCIES IN THE FIELD OF THE SOCIAL SCIENCES

"Economic Adjustment in a Machine Age": Ernest M. Patterson, professor and head of the Department of Economics, University of Pennsylvania. (Introduced by Dr. Johnson.)

"Communications and World Peace": Speaker to be announced.

"Unemployment and Its Social Significance": Arthur Woods, chairman of President Hoover's Emergency Committee for Employment. (Introduced by President Dercum.)

"Thou Shalt Not": James M. Beck, Member of Congress.

"Scientific Knowledge and Human Conduct": Speaker to be announced.

SECTION III. THE CHANGING WORLD

"Round Table Discussion and Recommendations": Edwin G. Conklin, professor of biology, Princeton University.

SCIENTIFIC NOTES AND NEWS

THE Executive Committee of the American Association for the Advancement of Science will hold its regular spring meeting at the Cosmos Club in Washington on Sunday, April 26, with a forenoon and an afternoon session. Business to come before the committee at this meeting should be in the permanent secretary's office, Smithsonian Institution Building, Washington, D. C., by April 20.

MAJOR GENERAL A. W. GREELY will observe his eighty-seventh birthday on March 27.

DR. ALEXIS CARREL, of the Rockefeller Institute for Medical Research, has been chosen as recipient of the Dr. Sofie A. Nordhoff-Jung prize for 1930 for his outstanding work in the field of cancer. Dr. Carrel will receive the diploma and a check for $1,000 from Dr. Nordhoff-Jung at ceremonies at Georgetown University on March 28. Ambassador von Prittwitz, of Germany, will read the diploma. Ambassador Claudel, of France, Dr. Carrel's native land, will attend, and Dr. W. Coleman Nevils, president of Georgetown University, will preside. The citation reads: "Dr. Carrel has added new laurels to his great achievements in surgery by expanding the method of tissue culture, and by its objective application he has vastly aided in the elucidation of fundamental questions relating to morbid growth, especially the development of malignant tumors."

ON the occasion of the seventy-sixth birthday of Mr. Andrew W. Mellon, Secretary of the Treasury, on March 24, the American Institute of Chemists announced the award of its medal jointly to Mr. Andrew W. Mellon and Mr. Richard B. Mellon for distinguished service to the science and profession of chemistry. Dr. Frederick E. Breithut, president of the American Institute of Chemists and head of the department of chemistry at the Brooklyn College, in making the announcement, said: "The institute medal is awarded annually for distinguished and outstanding services to the science and profession of chemistry. Mr. Andrew W. Mellon and Mr. Richard B. Mellon have contributed to the advancement of chemistry in its broadest aspects and have fostered the progress of industry by their far-seeing and unselfish efforts. Through the agency of the Mellon Institute of Industrial Research they have been leaders in the great forward march of the American chemical industry. This medal is awarded annually and usually to someone outside the chemical profession itself. In 1929, the award was made to Mr. and Mrs. Francis P. Garvan; in 1930, to Mr. George Eastman."

SIR JAMES HOPWOOD JEANS, who will receive a Franklin Medal from the Franklin Institute, Philadelphia, on May 20, will afterwards spend two weeks at the Mount Wilson Observatory.

DR. J. PLAYFAIR MCMURRICH, professor emeritus of anatomy at the University of Toronto, has been appointed a corresponding member of the Comité Internationale d'Histoire des Sciences of Paris.

DR. KONRAD E. BIRKHAUG, associate professor of bacteriology at the University of Rochester School of Medicine and Dentistry, has been elected a member of the Norwegian Academy of Sciences.

DR. ALBRECHT PENCK, of the University of Berlin, has been elected a corresponding member of the Geological Society of America.

DR. HANS WINKLER, professor of botany at Hamburg, has been elected a member of the Swedish Academy of Sciences.

DR. CARL CORRENS, professor of genetics at the University of Berlin, has been elected a member of the Academy of Sciences at Upsala.

THE National Geographical Society of Cuba, at its annual meeting on March 17, awarded its gold medal to M. Georges Claude, a member of the Paris Academy of Sciences, who has been using the waters of Matanzas Bay to generate electric current from thermal differences.

AT the University of North Carolina Dr. Herman Glenn Baity, professor of sanitary and municipal engineering, has been appointed acting dean of the School of Engineering in the place of the late Dean G. M. Braune.

DR. MONT R. REID, who has been associate professor of surgery in the College of Medicine of the University of Cincinnati, has been appointed head of the department of surgery. Dr. Reid succeeds Dr. George J. Heuer, who leaves at the end of the academic year to become surgeon-in-chief of the New York Hospital and professor of surgery in Cornell University Medical School.

DR. GEORGE R. BANCROFT, of the school of medicine of the University of West Virginia, has been appointed professor of physiological chemistry at Jefferson Medical College, Philadelphia.

DR. JOHN P. NAFE, professor of psychology at Clark University, has been appointed professor of psychology and head of the department at Washington University, St. Louis, effective on July 1, to succeed Dr. Edgar James Swift, head of the department since 1903, who is retiring.

DR. JEFFRIES WYMAN, JR., instructor in zoology at Harvard University, has been promoted to an assistant professorship.

MR. S. A. ROHWER, assistant chief of the Plant Quarantine and Control Administration of the U. S. Department of Agriculture, has been appointed assistant chief of the Bureau of Entomology, to succeed Mr. John E. Graf, now associate director of the U. S. National Museum. Mr. Frank H. Spencer, for the last six years administrative assistant to the Secretary of Agriculture, has been appointed chief of the division of administration in the bureau.

PROFESSOR HOMER G. TURNER has been appointed director of anthracite research for the Anthracite Institute of Lehigh University, and will devote much of his time for the next few years to that work.

MR. E. JACK COULSON, formerly of the department of chemistry of the Kansas State Agricultural College, has been appointed associate biochemist of the U. S. Bureau of Fisheries. He has been assigned to the laboratory of the South Carolina Food Research Commission at Charleston, to work upon the nutritive value of sea foods. The specific problem upon which Mr. Coulson is to be engaged at present deals with the mineral content of the oyster in relation to its value in nutritional anemia.

OFFICERS of the Columbia University Chapter of Sigma Xi elected at the recent meeting for a two-year term are: *President,* Professor Donald E. Lancefield, department of zoology; *Vice-president,* Professor Jerome J. Jerome, department of chemical engineering; *Secretary-Treasurer,* Dr. G. Marshall Kay, department of geology.

AT the meeting of the Pasteur Society of Central California on February 4, the following officers were elected for the present year: *President,* Dr. W. H. Manwaring, professor of bacteriology and experimental pathology, Stanford University; *Vice-president,* Dr. W. T. Cummins, pathologist, Southern Pacific Hospital, San Francisco; *Secretary-treasurer,* Miss Beatrice Howitt, associate in research medicine, Hooper Foundation, University of California; *Councillors,* Dr. C. M. Haring, professor of veterinary science, University of California; Dr. L. B. Taber, doctor of dental surgery, San Francisco. The speakers of the evening were: Mr. B. S. Henry, assistant in veterinary science, University of California, Berkeley, who presented a paper on "Bacterial Dissociation," illustrated with lantern slides, and Dr. J. N. Force, professor of epidemiology, who spoke on "Daniel Sutton and the Revival of Variolation."

AT the request of the American Petroleum Institute, the Secretary of the Interior, Dr. Ray Lyman Wilbur, as chairman of the Federal Oil Conservation Board, has announced the appointment of a Voluntary Committee on Petroleum Economics to survey the supply and demand factors in the petroleum industry for the six-months period beginning April 1 and ending September 30. The committee consists of: E. B. Swanson, chief economist, U. S. Bureau of Mines, chairman; John W. Frey, Bureau of Foreign and Domestic Commerce; Martin Van Couvering, petroleum engineer, Los Angeles; Alfred G. White, National Industrial Conference Board, New York City, and Howard Bennette, Western Petroleum Refiners Association.

DR. O. E. BAKER, of the Bureau of Agricultural Economics, has been requested to assist with the work of the President's Committee on Recent Social Changes, of which Dr. Wesley Mitchell, of the National Bureau of Economic Research, is chairman. Dr. Baker, together with Dr. S. G. Tryon, of the Bureau of Mines, will prepare the portion of the report dealing with natural resources, the former preparing the part relating to land or agricultural resources, and the latter the part on mineral resources. Dr. Baker has been authorized to spend part of his time during the coming year on this work.

AN Associated Press dispatch reports that an investigation of the causes of the recurrence of malaria is planned at the Gorgas Memorial Institute of Tropical and Preventive Medicine at Panama. The tests will be conducted under the direction of Dr. W. H. Taliaferro, professor of parasitology at the University of Chicago.

LEAVE of absence has been granted for the first semester of the years 1931–1932 to Professor William H. Hobbs, of the University of Michigan, who expects to attend the International Geographical Congress to be held in Paris in September of this year and who will carry out certain field studies in geology in addition to completing a book on glaciers which he expects to publish in the near future.

PROFESSOR GEORGE D. HUBBARD, head of the department of geology and geography of Oberlin College, is continuing his work in Europe. He has spent the three winter months in the Balkans and Near East. Maps, photographs and specimens are being collected and sent home for further study and as helps in teaching.

THE HONORABLE S. F. MARKHAM, secretary of the Museums Association of Great Britain, is now in the United States. He plans to visit the larger museums in the eastern part of the United States and Canada.

DR. JOHN C. MERRIAM, president of the Carnegie Institution of Washington, delivered an address on March 19 before the Washington Academy of Sciences on "The Unity of Nature as Illustrated by the Grand Canyon."

DR. FREDERICK G. NOVY, professor of bacteriology in the University of Michigan Medical School, will deliver the annual Kober Lecture at Gaston Hall, Georgetown University, on March 28. Dr. Novy's subject will be "Respiration of Micro-Organisms."

DR. KARL F. MEYER, director of the George Williams Hooper Foundation for Medical Research, University of California, will deliver the seventh Ludvig Hektoen Lecture of the Billings Foundation before the Institute of Medicine of Chicago on April 24. Dr. Meyer will speak on "The Animal Kingdom—A Reservoir of Disease."

DR. HERBERT A. EVANS, of the University of California Medical School, will give the annual Charles Sumner Bacon Lectures at the University of Illinois College of Medicine. The first lecture on March 31 will be on "The Hormones of the Hypophysis," and the second on April 1, on "The Relation of the Hypophysis to the Reproductive System."

THE *Journal* of the American Medical Association reports that Dr. Alfred F. Hess, New York, delivered the Frederick A. Packard Memorial Lecture before the Philadelphia Pediatric Society on March 10, on "Ultraviolet Irradiated Ergosterol and Irradiated Foods," and on March 12 Dr. Warren H. Lewis, Baltimore, presented a motion picture of tissue cultures of human and mammalian tumor cells before the Pathological Society of Philadelphia.

DR. T. A. KIESSELBACH, professor of agronomy in the College of Agriculture, of the University of Nebraska, gave the second series of annual lectures under the Frank Azor Spragg Memorial Fund, early in March, at Michigan State College. This memorial is in honor of Professor F. A. Spragg, who was in charge of plant breeding work at the Michigan Agricultural Experiment Station from 1906 until his death in 1924.

THE Michigan Academy of Science, Arts and Letters held its thirty-sixth annual meeting in Ann Arbor, on March 19, 20 and 21. An extensive program comprising two hundred addresses and papers had been prepared. Professor Edwin G. Conklin, of Princeton, addressed the members on "Fitness the Greatest Problem of Biology"; Professor Leroy Waterman, director of the Michigan-Toledo-Cleveland Expedition in the Near East, spoke on "The Fourth Season at Seleucia on the Tigris." Dr. Eugene S. McCartney, of the University Graduate School, gave the presidential address on "Folklore Heirlooms."

THE 1931 meetings of the American Society of Ichthyologists and Herpetologists will be held at the Academy of Natural Sciences of Philadelphia, from May 11 to 13. The arrangements are in charge of a local committee, consisting of Messrs. Fowler, Dunn and Green. In the business meeting, called for 10 A. M. on Monday, May 11, there will come up for discussion the matter of the support of the *Biological Abstracts* and the *Zoological Record* and other items. Sessions for the reading of papers will be held on Monday and Tuesday. In addition there will be papers of interest to aquarists and an exhibit by Philadelphia fish fanciers. An excursion to the Philadelphia Aquarium and the Philadelphia Zoological Gardens is proposed. Those intending to address the meeting are requested to send titles to Dr. E. R. Dunn, Haverford College, Haverford, Pennsylvania, before May 1.

RECENT meetings of the Toronto center of the Royal Astronomical Society of Canada have included the following lectures: "Star Clusters: Recent Investigations with Reference to Their Bearing on Stellar Evolution," Dr. R. K. Young, Toronto; "Recent Geophysical Investigations in Mineralized Regions," by Professor Lachlan Gilchrist, Toronto, and A. H. Miller, Dominion Observatory, Ottawa; "Telescopes for Amateurs, and How to Use Them," by John A. Marsh, Hamilton, Ontario; "The Sun as a Source of Energy," by Professor D. S. Ainslie, Toronto. The program for March and April includes the following papers: March 24—"The Stars in Navigation," by Commander J. M. de Marbois; April 14—"Some Mathematical Paradoxes," by Professor E. Beatty; April 28—"The Nebulae Outside the Galactic System," by Dr. H. H. Plaskett, Victoria.

Industrial and Engineering Chemistry reports that the British Institute of Metals and the Iron and Steel Institute have been invited by the American Institute of Mining and Metallurgical Engineers to hold their respective autumn meetings in New York in September, 1932, the meetings to be followed by a tour in the United States and Canada. The detailed program for these joint meetings has now been issued. The sessions will begin Monday, September 12, 1932, in the Engineering Societies Building, New York, and the tour of industrial cities will end in Montreal on September 29. The English party will sail from that port on September 30.

THE *Journal* of the American Medical Association reports that the Rockefeller Foundation has offered to assist in the establishment of a School of Hygiene and Public Health in Tokyo. It is said that buildings will be erected at a cost of $5,000,000. The Japanese government has nominated a special committee on organization which consists of Dr. Hayashi, dean of the medical department of the Tokyo Imperial University; Dr. Kitajima, dean of the Keio Medical College, and Dr. Teusler, chief of St. Luke's International Hospital; Chairman, Mr. Akagi, chief of the Sanitary Bureau; Commissioners, Drs. Nagayo and Miyagawa, of the Imperial University of Tokyo and the government Institute for the Study of Infectious Diseases; Drs. Miyajima and Hata, of the Keio Medical College and the Kitasato Institute; Dr. Sato, of St. Luke's International Hospital, and Drs. Kusama and Noheji, of the Sanitary Bureau of the Home Ministry.

THE *Journal* of the American Medical Association reports that the Southern Pacific Company recently offered the use of a completely equipped laboratory on wheels to the University of California Hooper Foundation for Medical Research to assist in answering emergency calls throughout the state for help in fighting epidemics. The car has been rebuilt to fill the needs of a staff of public health workers, either for emergencies or for routine examinations and educational programs, and is available at any time for use anywhere along the railroad's lines. It has a well-equipped bacteriologic and chemical laboratory, an x-ray room with facilities for developing films, a waiting room, examining room, quarters for two physicians and a technician, a galley and combination dining and record room, and quarters for a crew of two. Dr. Karl F. Meyer and Dr. Jacob C. Geiger, of the foundation, have already made use of the car in demonstrations before various medical associations.

LEGISLATIVE appropriations for the support of Kansas State College of Agriculture and Applied Science for the two years beginning July 1, 1931, amount to $2,751,000. They include $40,000 for research on animal diseases, $40,000 for laboratory equipment, $10,000 for continuing the soil survey, $120,000 for branch experiment stations, $44,000 for soil and crop experiment fields and $20,000 for completing the equipment of the college library.

THE bill extending the Adirondack Park to an area of 4,604,000 acres and making it the largest public park in the United States has become law. The park area will now take in 1,550,000 acres, of which 1,201,000 are privately owned and 349,000 state owned. Within the greater park there will be 2,636,000 acres of privately owned and 1,968,000 of state-owned lands.

DISCUSSION

THE IMPORTANCE OF GIVING PAGE REFERENCES IN DESCRIPTIONS OF PLATES

IT may fairly be assumed that it is the desire and intent of authors and editors of scientific publications to render their work as complete and readily usable to the scientific public as possible. There is, however, one point that is too generally overlooked that is believed to be of very essential importance to one who is reading or otherwise making use of a scientific publication. This point is the matter of giving page references in the description of plates. When the paper is a small one, it is of little importance, or even quite unnecessary, but in large papers or monographs the lack of page citations in descriptions of plates entails some, even considerable effort on the part of the reader. If a paper, zoological or botanical, is a systematic one, it may be assumed that the sequence of plates corresponds fairly closely with that of the text. Even then, however, exigencies of the size or character of figures often require considerable irregularity in their order.

When a reader sees a figure on a plate and wishes to consult the text where the figure is described, if no page reference is given, the quickest method usually is to refer to the index. In very many publications, however, no index is given. Lacking an index, the reader must then turn the pages of the text in quest of the desired description of the said figure. If it is a systematic paper on a subject with which the reader is familiar, the required page can usually be found after a moderate search. If, however, it is not a systematic paper but, for example, morphological, then without a page reference or index it may become a serious, even a difficult matter to find the place in the text where a given figure is described.

Recently this difficulty of finding the description of figures in the text was brought home to me strongly in making use of a French morphological memoir with over 300 pages of text and 32 plates. No page references were given in the description of plates and there was no alphabetical index. As I was fortunate enough to possess a copy of the work, it was possible to note the necessary page references on the plates as ascertained by carefully going through the text, but it was a great labor. All this would have been saved and the memoir much improved by simply adding page references in the description of plates.

In doing such work, one may not succeed in finding the description of a given figure. That leaves a student in a quandary. It might be thought, and usually correctly so, that if there is a figure on a plate it is sure to be considered somewhere in the text. On the other hand, I know an author who published many figures that certainly are not considered in the text. To hunt for a description of a figure in the text and not find it, then feel that one must have overlooked it and hunt again, perhaps without avail, but surely with loss of time and vexation of spirit, is most trying. The author of a memoir is in a position to add page references in description of plates with comparatively little trouble, and with an immense gain to the reader. The cost of such insertions is so trifling as to be negligible. Of course it should be borne in mind that in the preparation of manuscript one should write: page, or p. 000, so that space will be available for the printer to insert the required page numbers.

In some publications page references are given in descriptions of plates; as such may be mentioned those of the New York State Museum, the paleontological publications of the United States Geological Survey, and largely in the well-known Challenger Reports. In using such publications it is immediately felt what a convenience and comfort it is to be able to turn directly to the indicated descriptive page without the labor of hunting for the same.

I adopted the method of giving page references in descriptions of plates in my first considerable paper, published some forty years ago, and have employed the same method in what few large papers I have since published with one exception, in which the editor refused to allow page references as they did not accord with the system adopted in that publication. He apparently felt that adherence to system was of more importance than the convenience of the reader.

It appears that there is every argument in favor of giving page references in descriptions of plates, and no argument against it, excepting in so far as the trouble to the author may be considered an objection.

It is highly desirable to have the descriptions of plates facing the plates, but as it costs more, it is not always feasible. When descriptions are printed so as to face the plates, it seems that it would be very desirable to give such descriptions page numbers, as is done in some publications. The main object of this is that a subsequent writer who may wish to refer to them may do so by quoting the *page number*, rather than by the alternative of *page facing plate blank*, which is somewhat lengthy and cumbersome.

Another point that is worth consideration is that in an index to a publication, when an item has references to two or more pages in the text, it is of convenience to have the principal reference indicated by heavy-faced type. Such a method, where adopted, facilitates the finding of the principal reference.

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CYTOPLASMIC INHERITANCE OF MALE STERILITY IN ZEA MAYS

WHEN the transmission of a character has been conclusively proved to be independent of nuclear factors it must necessarily be inherited through the cytoplasm. Such a mode of inheritance is called cytoplasmic in contrast to the better understood Mendelian inheritance. The few cases of cytoplasmic inheritance that have been clearly established are concerned with certain chlorophyll characters in plants in which the nature of the cytoplasm or plastids contributed by the maternal parent or, more rarely, by either parent, determines whether the progeny shall be green or abnormal (white, pale green, or variegated). There is at least one case (in flax) where the interaction of specific genes with the cytoplasm of one of the parental types results in male sterility; this can not be considered as purely cytoplasmic inheritance, since nuclear factors are also involved.

Recently, investigations of the inheritance of a male sterile line of maize found in a collection made by R. A. Emerson and F. D. Richey at Arequipa, Peru, indicate that the sterility is determined entirely by the non-nuclear elements of the maternal gamete. The cross of the original male sterile plant by an unrelated normal gave an F_1 of 45 sterile individuals. The F_2 cultures consisted of families which bred true for male sterility, and of others that gave normal-appearing individuals in addition to sterile plants. Races in later generations have been established which (1) breed true for male sterility, (2) throw male sterile and normal plants, and rarely (3) are completely normal. There is no female sterility apparent.

The analyses made permit the following statements concerning the inheritance of the male sterile character:

1. Replacement of the original chromosomes in the

male-sterile line with chromosomes from normal lines has no effect on the sterility. Through the use of Mendelian markers (genes) it was possible to show that 9 of the 10 linkage groups were free from any factor or factors causing the sterility. Tests are incomplete for the tenth group.

2. Pollen from partially sterile plants carry no transmissible factors, either genic or cytoplasmic, for male-sterility.

3. The genetic constitution of the male parent crossed with a male sterile individual has no demonstrable effect on the degree of sterility.

4. Cytological investigation shows the meiotic divisions in microsporogenesis to be normal. The degeneration of the pollen occurs usually after the first vegetative division.

MARCUS M. RHOADES

CORNELL UNIVERSITY

TREES WITH TWISTED BARK

IN SCIENCE for February 13 there is an article[1] by Mr. C. K. Wentworth on "Twist in the Grain of Coniferous Trees." Mr. Wentworth points out that the bark of conifers often shows a decided twist, and that in the cases of several hundred trees which he has examined the twist is usually right-handed. He adds that he has not noticed any similar twist in deciduous trees, but supposes it may perhaps occur.

These statements have recalled to me a twist which I noticed some years ago in the barks of maples and elms. I supposed that if the effect were at all common it was probably well known to botanists. However inquiry from two botanists did not indicate that either of them happened to know of it, and in connection with Mr. Wentworth's paper I am venturing to report my observations.

The number of trees which I have observed is small, and all of them are in the city of Northampton, Massachusetts. The maples often show a rather pronounced twist in the bark, and this twist seems to be almost always right-handed. On elms a twisted bark seems to occur less frequently, but when it does occur it is usually left-handed. In one location there are two large elms with strong left-handed twist growing near to a large maple that has a strong right-handed twist.

The number of trees which I have observed is too small to permit of drawing any general conclusions, but in this small number the twist seems to be more frequent in maples than in elms, and seems to be usually right-handed in maples and left-handed in elms.

ARTHUR TABER JONES

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[1] Chester K. Wentworth, SCIENCE, 73, 192, 1931.

PANAMAN OR PANAMANIAN?

IN numerous journals, including SCIENCE, and in the press, the use of the adjectival form, Panamanian, has been noted. The proper noun, Panama, does not seem to differ in any essential way from the many other proper names, geographic and personal, which end in "a."

The well-nigh universal practice in forming the adjective from such nouns is the simple addition of a final "n." Thus African and American instead of Africanian and Americanian. Other common examples of such words are: Alabama, Atlanta, Asia, Australia, California, Caligula, Dominica, Florida, Guatemala, Inca, Iowa, Korea, Maya, Montana, Nebraska, Nicaragua, Olympia, Peoria, Persia, Polynesia, Russia, Seneca, Utica, Utopia, and Volga, and most of the rest of the long roll. For these we write, in the adjective form, Albertan, Incan, Mayan, Nebraskan, Polynesian, Utican, etc., but never the double suffix, as Iowanian, Mayanian or Nebraskanian. Therefore, why Panamanian instead of Panaman?

There are some exceptions to the general rule, of course. It would not be our English language if there were not. Canada becomes Canadian and Carolina is transformed to Carolinian, probably partly from ideas as to euphony and partly from resemblance to those adjectives formed by adding "n" to a final "ia," as, Asia: Asian. But, even so, one never sees Canadanian or Carolinanian, which are exact counter-parts of Panamanian.

Another exception is China, although there is nothing wrong with Chinan except its unaccustomedness —and one never meets with Chinanian. Let us make it unanimous for Panaman!

CARLETON R. BALL

UNIVERSITY OF CALIFORNIA

ESTRUS

THERE has been recently some discussion in your columns on the right use of Greek and Latin case endings in scientific nomenclature. May I draw to your attention the misuse of the word "Estrus" which has crept into the literature. This word was introduced by Heape to denote the period of sexual desire in the female and was correctly spelt by him "Œstrus," but many writers prefer the form "Estrum." It is inconceivable that the gadfly which chased the sprightly heifer, Io, into Egypt could have been anything but masculine, so this form must be, not the neuter gender but the accusative case, which is undefendable. The adjectival form "estrous" is often badly distorted too. The modifications "postestrum," "metestrum," "diestrum" and "anestrum" are

naturally correct, being the accusative cases after the prepositions.

In regard to the perversion of the initial diphthong, I have nothing to say; that is usually the result of editorial pressure and it is far from my desire to kick against the pricks.

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CORNELL UNIVERSITY

AN APOLOGETIC CORRECTION

IT has come to my attention that I have, on the basis of insufficient information, done an injustice to the memory of George Compere in my recently published "History of Applied Entomology." In that book I have indicated that George Compere was responsible for the introduction and establishment in California, under the impression that it was a primary enemy of the black scale, of a secondary parasite (now known as *Quaylea whittieri*) which has destroyed very largely a very important primary parasite of the scale.

Mr. Harold Compere, son of the late George Compere, himself an advanced student of parasites and a thoroughly sound scientific worker, has access to the correspondence of his late father and has found in this correspondence a distinct warning sent by George Compere to Alexander Craw (at that time in charge of the California state introductions of parasites) to the effect that this particular parasite might be a secondary and that he should be very careful about it.

This particular parasite belongs to the subfamily Encyrtinae, and at that time I knew no hyperparasite belonging to that group. Mr. Craw sent specimens to Washington for naming and for advice. I sent him a manuscript name given to it by the late Dr. W. H. Ashmead and told him that I knew of no hyperparasites of this group. This would seem to place the onus on me, and would do so were it not for the fact that I was in the habit of visiting California each year and had repeatedly talked with Mr. Craw on the subject of these parasites, warning him again and again not to liberate anything without making careful life history studies in the little quasi laboratory that he had fitted up in his office near the ferry building in San Francisco.

I gladly publish this statement, since George Compere was at one time a friend of mine and since I have the highest admiration and regard for his able son.

L. O. HOWARD

WASHINGTON, D. C.

SCIENTIFIC BOOKS

La Parthénogenèse. By A. VANDEL. Vol. 7 of Bibliothèque de Biologie Générale. Paris; Gaston Doin et Cie., 1931, 412 pp., 42 figures in text. Price 32 francs.

IT is a matter of surprise that prior to Professor Vandel's publication no thorough review of the subject of natural parthenogenesis had appeared, despite the prevailing tendency to summarize and digest the subject-matter of the different branches of biology. It is true that in 1920 Winkler collected a very large amount of the available findings in this field, but, aside from using it in weighing Ernst's hypothesis of hybridization as a cause of apogamy among plants, he made little use of this gathering of information. Vandel's book is therefore the first to give an adequate treatment of a subject, the extent and difficulty of which are attested by the 700 odd titles in the bibliography (which lists publications up to and including 1929). In accomplishing his task, Vandel takes up the subject under a number of wisely chosen headings. The treatment of the field observations and the breeding work under these headings is followed by a critical examination of the cytological findings, and this in turn is succeeded by a consideration of the possible points of contact with artificial parthenogenesis and a discussion of the question of sex determination. Throughout, Vandel gives a concise and clear exposition of the questions at issue and I am in sympathy with his unexpressed view that in the present state of the subject it is always preferable to broach an hypothesis rather than to leave a question entirely open. If his wholly admirable suggestions are interspersed with a few that will hardly stand up under a strict test, it must be said that all are advanced with a commendable caution. Vandel's firm and well-founded insistence that haploid and diploid parthenogenesis are basically unrelated I can only applaud.

The book has few faults. The cytological illustrations are often inadequate, but this criticism applies more to their reproduction than to their selection. The fact that the bibliography is given under chapter headings instead of being presented in one continuous alphabetical list is not without its disadvantages, although the numbering of the titles is of some aid in locating references.

It is with pleasure that I commend this work, which, far from betraying the drudgery which must have accompanied its preparation, is written with spirit and brightness.

FRANZ SCHRADER

DEPARTMENT OF ZOOLOGY,
COLUMBIA UNIVERSITY

Star Clusters (Harvard Observatory Monographs No. 2). By HARLOW SHAPLEY. xi + 276 pp. McGraw-Hill Book Company, New York, 1930. $3.00.

ONE of the reasons why many star clusters are worth studying is that they present stars of different physical characteristics at practically the same distance. The possibilities here offered have been utilized with startling success.

"Star Clusters" tells the story of the exploration of this interesting field of modern astronomical activity. The author of the book has had a lion's share in the advancement of the subject. The fifteen years of active study of star clusters have not lessened his enthusiasm for the subject, as is apparent from every page of the book.

The book deals with galactic and globular clusters but with the latter in the forefront. It does not pretend to give an exhaustive treatment of all the ground it covers but contains abundant references to subjects treated elsewhere. As part of its plan, and a very welcome part to its readers, it presents as one unit Professor Shapley's own researches, published in numerous papers, now extended and amended where necessary.

The author states in his preface that he has postponed the publication of this monograph till a revised system of parallaxes for globular clusters could be available. It is evident how much time-consuming labor members of the Harvard Observatory Staff, under Professor Shapley's direction, had to accomplish in order to provide for the finishing touch to many chapters.

The period luminosity curve for Cepheid variables is newly derived from a richer material of variables in the Small Magellanic Cloud only.

Theoretical considerations in connection with the period-luminosity relation are presented in two separate paragraphs (22 and 51). It is to be regretted that the subject has not been treated as a whole.

Paragraph 44 gives some historical notes in connection with the period luminosity relation. Hertzsprung is given credit for his early work on Cepheid variables. But the interesting fact that he was the first to use the relation for the determination of the distance of the small Magellanic Cloud is not stated. In the same paragraph, when reference is made to "some vigorous critical discussion of the data on galactic Cepheids," Dr. Schilt's contributions are not mentioned.

In recent years much has been written about the transparency of space. An interesting chapter is devoted to this subject of intrinsic importance when one deals with the huge distances of globular clusters and extra-galactic nebulae.

In a chapter, "Data Bearing on the Origin of the Galaxy," the knowledge of star clusters is used as a basis for an interesting tentative discussion of the galactic system as a unit of higher order in the universe.

Forty-six pages at the end of the book are devoted to four valuable appendices. They give catalogues of globular and galactic clusters and a very complete bibliography of star clusters containing 812 titles.

It may be a decided disadvantage when the author's own researches have covered practically the whole subject treated in a book. His presentation will almost necessarily be too subjective. In this book we frequently notice such a lack of objectiveness when important contributions of others are reviewed in a few words. This is especially regrettable if, on this account, work of original character does not receive proper emphasis.

DIRK BROUWER

YALE UNIVERSITY OBSERVATORY,
FEBRUARY 13, 1931

SCIENTIFIC APPARATUS AND LABORATORY METHODS

A DEVICE FOR WASHING TISSUES

IN our laboratory it became necessary to devise an apparatus for washing fixed tissues in running water. It was desirable to arrange this apparatus to accommodate the material of a technique class of about a half-dozen students so that all individuals could use it without interfering with each other's material or hampering the efficiency of the apparatus.

The apparatus is so constructed that any one who is handy with a pair of tin shears and a soldering iron can put it up in an hour's time from a few scraps of thin galvanized iron at no cost whatever.

Essentially the apparatus consists of a tank (K), a rack (E) to hold the tubes containing the material and an overhead trough (C) to distribute the water. Fig. 1 shows the apparatus as it appears when assembled. It is set up from only three parts that need to be cut to pattern and two small tubes. The pattern of the tank itself is shown in Fig. 4. Dotted lines indicate folds in the metal. The nature of such folding will be apparent at once by reference to Fig. 1. The holes at A are to take screws to support the whole apparatus on the under side of a shelf above the laboratory sink. The hole (S) shown in Fig. 4 (not visible in Fig. 1) is a drain, but kept closed with a cork when the apparatus is in use. The overflow pipe (L, Fig. 1) is soldered over the hole L (Fig. 4) and the inflow pipe (M, Fig. 1) is soldered over the hole M (Fig. 4). These pipes are easily fashioned from small rectangular pieces of the sheet

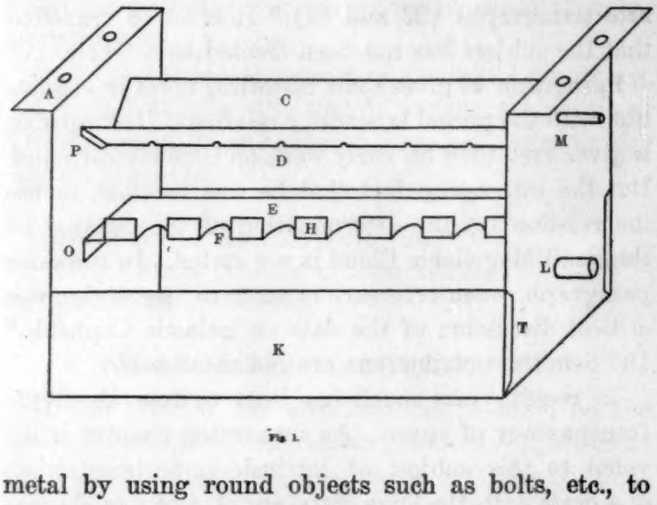

Fig. 1.

metal by using round objects such as bolts, etc., to hammer the metal around. Overlapping joints (T) are soldered to the upright ends of the tank so that the joints are water-tight.

The pattern of the rack is shown in Fig. 2. Its nature is apparent when reference is made to Fig. 1. The slots (F) are made by drilling the metal first with round holes of appropriate size and properly spaced. In our apparatus these holes were made

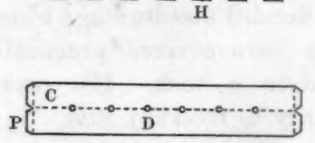

Fig. 2.

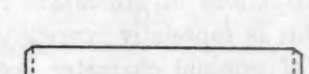

Fig. 3.

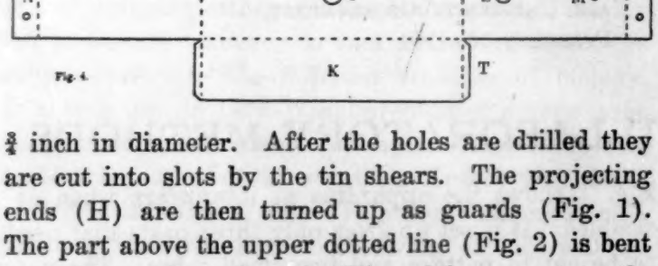

Fig. 4.

$\frac{3}{4}$ inch in diameter. After the holes are drilled they are cut into slots by the tin shears. The projecting ends (H) are then turned up as guards (Fig. 1). The part above the upper dotted line (Fig. 2) is bent at a right angle to the rest (E) and forms a strengthening flange not visible in Fig. 1. The ends (O) are turned and soldered down to the ends of the tank as shown in Fig. 1.

The construction of the water-distributing trough is simple (pattern in Fig. 3). It is merely a V-shaped trough (C, Fig. 1) with nail holes (D) punched in its bottom in such a manner that they will be properly centered over the slots (F) in the rack. The ends (P), as in the case of those of the rack, are turned over and soldered down to the ends of the tank.

The outlet pipe (L) is set so that the top side of it is about $\frac{1}{8}$ inch below the top of the side (K) of the tank and it is sufficiently large to be a positive drain. The inlet pipe (M) may be much smaller.

As stated before, our apparatus is fastened on the under side of a shelf over the laboratory sink. Water is supplied through a rubber tube slipped over the pipe M. In order for the apparatus not to interfere, even when in constant use, with ordinary use of the water faucet at the sink we had our college engineer set an $\frac{1}{8}$ inch petcock permanently into the faucet back of its valve.

Ordinary $\frac{3}{4}$ inch flanged test tubes make excellent tissue holders. These are cut off about 2 to $2\frac{1}{2}$ inches below the flange, or short enough to clear the bottom of the tank and permit a free flow of water through them. These cut ends are closed with silk or with bolting cloth. These tubes containing the tissues are suspended in the slots in the rack. The water is started and allowed to flow into the trough. It drips through the holes (D) into the tubes suspended in the slots, fills the tank and overflows through the outlet tube (L). The overflow may be allowed to fall directly into the sink or it may be carried to any desired point with a large rubber tube.

The tissue-containing tubes are constantly suspended in water even should the flow be stopped. While the water is flowing clean water constantly passes the tissues. The rate of flow may be regulated by the petcock.

Such an apparatus as this may be made of any suitable size. More or less slots may be made according to the number of students using the apparatus or the amounts of tissues being washed. Our apparatus measures $10\frac{3}{4}$ inches in length and has six $\frac{3}{4}$ inch slots. These slots may, however, be made to accommodate any size of tube.

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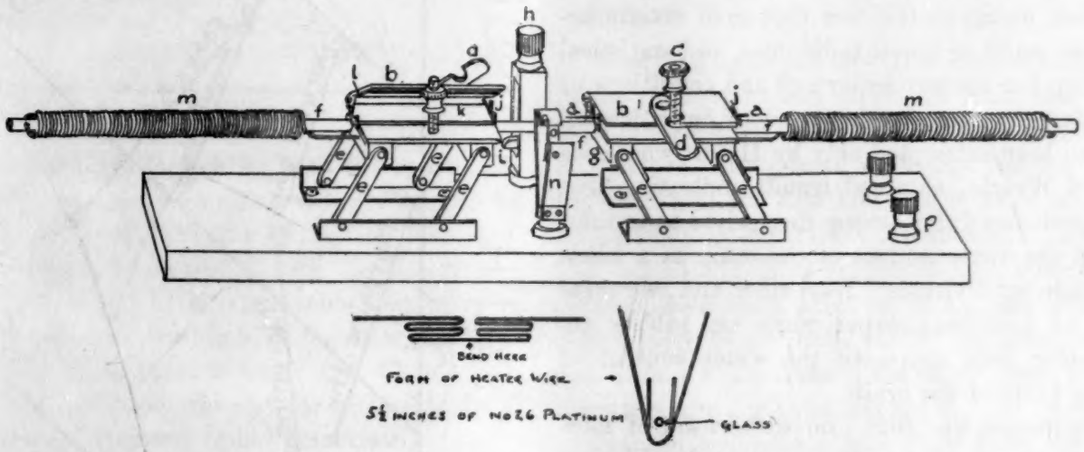
A MACHINE FOR PULLING GLASS MICRO-PIPETTES AND NEEDLES

IN designing a machine for this work a study was first made of the hand movements of an expert in making needles and pipettes. The essential movements seemed to be a removal of the glass from the heater at the correct temperature followed by a rather quick horizontal pull-out.

In the machine as designed a parallel motion was devised which, when the glass becomes plastic enough to stretch under a light pull, lifts the glass up and out of the heater, and, at the same time, increases the pull by an increase of leverage. The result is a rapid pull-out at the correct instant.

The machine as shown in the diagram is in its final

position after pulling two needles, and one needle (a) is still held in the machine by the clamp (b) though the locking nut (c) has been unscrewed (much more than is necessary to release the latch (d)). It is obvious from the drawing that the clamps (b) remain always parallel to the base due to the hinged side bars (e) but perhaps it is not so clear that the alignment rod (f) passes with a sliding fit through the cross-bars (g) of the clamps (b) so that the two clamps must move up and down together, always remaining in alignment with each other. To "set" the machine the clamps are pressed down until, by turning the knurled knob (h), the retaining bar (i) may be swung over the alignment rod (f). The clamps are then opened and a glass rod or capillary of double length is dropped between the guides (j). This rod or capillary will rest on the leather pads (k) and when the clamps are closed and latched will be held firmly by the rubber pads (l). The retaining bar (i) may now be swung off, without changing the position of the machine, though the glass will now be under the tension of the springs (m). In this position the glass rod or capillary will pass through the heater (n) and upon switching on the current the glass will become softened. It will pull out, first slowly and then, as the clamps rise, the action will become rapid, ending with a quick pull-out, and two needles or pipettes will be pointed and ready for bending.



This machine has a number of elements which can be adjusted to give any form of needle or pipette point desired. This is necessary as different types of points are often required, but no change in adjustment is necessary for glass of different diameters.

The heating element is a platinum wire in a V-shaped holder of mica. A resistance must be used in series with the heater with a snap switch to turn on and off. If the platinum wire is too small it may burn out. At least size No. 26 should be used. The best form of the wire is shown in the diagram. The width of the heater determines the length of glass softened and so controls the length of the tapering shank of the point. With the form shown this will be about correct, but the shank can be lengthened by spreading the loops of the wire if desirable. The temperature of the heater depends upon the current which flows and this can be adjusted by the series resistance to give a safe temperature which will not burn out the platinum. At this temperature, the color of the wire is a bright yellow. A current of 7½ amperes may be used for No. 26 platinum wire.

The heater is adjustable in position and should be set squarely under the glass rod. The heater can be raised and lowered and the loops may be bent in and out. If the heater is too low or too open at the top of the loops the heat will not be maintained long enough as the glass rises, and the final taper may be too short or the tip broken. On the other hand if the heater is too high the final taper will be too long or the tip fused.

One other adjustment that can be made is the position, up and down, of the bar that locks the machine while the glass is being clamped in place. The lower this bar is adjusted the less will be the initial tension on the glass. It should be kept fairly low.

It will be seen that each of these adjustments affects the others. Thus an increase of heater current or a raising of the heater, or a lowering of the locking bar will all act to increase the heat delivered to the glass. The main thing seems to be a rather intense heat at the start, maintained as the glass rises until just before the pull-out. The exact setting, however, can only be made experimentally.

With the machine adjusted to give the type of point desired, it is possible to turn out pipettes or needles at the rate of four to six per minute. This machine is now in use in Dr. Chambers' laboratories.

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SPECIAL ARTICLES

BRAIN WATER MOVEMENT DURING ANESTHESIA

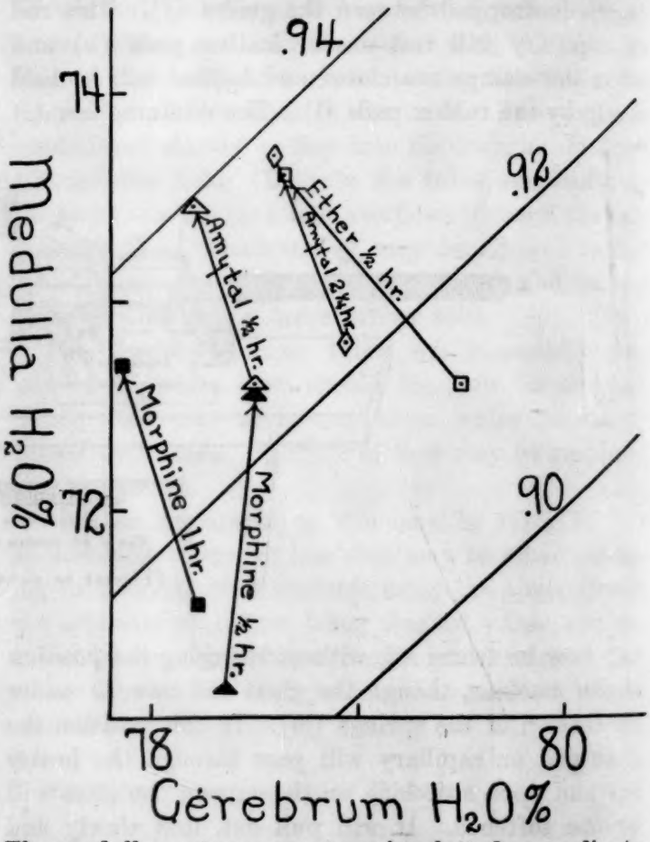
ALTHOUGH dehydration has for nearly half a century[1] been considered a probable accompaniment of anesthesia, apparently direct confirmation of this fact on nerve cells has never been reported. Suggestive analogies, however, have been brought forward in connection with the narcosis of plants. Furthermore Knaffl-Lenz[2] has shown that the swelling of red blood cells in hypertonic saline solutions is prevented by low concentrations of alcohol. He confirmed this with other anesthetics which also dehydrated gelatin plates. Similarly, Kochmann[3] inhibited the acid swelling of fibrin particles by anesthetics. This investigator further found the narcosis of frogs' gastrocnemii by chloroform, chloral and a series of alcohols accompanied in each case by reversible dehydration.

The water content of nerve centers is difficult of investigation, owing to the fact that each determination must be made on a new individual, and statistical data built up for the particular age and conditions of the animals. Apparently this type of investigation has hitherto been attempted only by Haldi[4] who, with Larkin and Wright, obtained results indicating that various anesthetics differ among themselves as to their effect upon the water content of the brain as a whole and of certain subdivisions. Both ether and morphine in three- or four-hour experiments on rabbits increased rather than decreased the water content of the various parts of the brain.

Brain hydration was found on withdrawal of morphine from young adult rats and dogs by Flowers and Dunham[5] working with the writer; this led to an attempt to learn more of the relations of brain water to narcosis. In our first experiments when a single dose of morphine was given to rats, the cerebrum was found somewhat dehydrated after two hours. A year ago, Dunham, Ellerbrook and I, in confirming this fact, showed that several hours after morphine injection the dehydration occurred both in cerebrum and medulla; but *during the first two hours* a marked difference was noted in that while the cerebrum usually lost water, the primary effect upon the medulla was *hydration*. Thus we have in early morphine narcosis a condition in which the ratio medulla H_2O/cerebrum H_2O is markedly increased.

The use of the medulla H_2O/cerebrum H_2O ratio tends to minimize individual variations between animals. For example, one rat as a whole might be wetter than another without a change in this ratio. When it does change a possible shift of water from one part of the brain to another is thereby suggested.

Recently Flowers and I have extended the anesthetic work to include amytal and ether, and have confirmed the increase in the medulla H_2O/cerebrum H_2O ratio in rats, and in the case of ether in young rabbits as well. While this ratio is normally around .92, it may rise to nearly .94 in early anesthesia, as shown by the diagonals in the accompanying figure.



The medulla water percentage is plotted as ordinate against the cerebrum water percentage as abscissa, and the dehydration of the cerebrum shown in four out of five cases is quite overshadowed by the hydration of the medulla.

While all the anesthetics mentioned tend to increase the general muscle tone of rats, a true "stage of excitement" occurs only after ether. In the above-mentioned experiments it was brief. Ether excitement intentionally prolonged for half an hour in one rat and two rabbits produced no significant increase in the medulla H_2O/cerebrum H_2O ratio. Furthermore, one half hour muscular activity in an unanesthetized rat gave only a normal figure. Hence the water shift described appears directly associated with the process of *narcosis*, not with preliminary stimulation of any sort.

[1] V. E. Henderson, *Physiol. Rev.*, 10: 176, 1930.

[2] E. von Knaffl-Lenz, Pfluger's Arch. Physiol., 171: 51, 1918.

[3] M. Kochmann, *Biochem. Zeitsch.*, 136: 49, 1923.

[4] J. Haldi, J. Larkin and P. Wright, *Amer. J. Physiol.*, 88: 112, 1929.

[5] S. H. Flowers, E. S. Dunham and H. G. Barbour, Proc. Soc. Exper. Biol. and Med., 26: 572, 1929.

H. G. Barbour, B. E. Russell, S. H. Flowers, E. S. Dunham and L. G. Hunter, *Amer. J. Physiol.*, 90: 273, 1929.

The results are summarized in the following table where fifteen control rats are seen to have given an average medulla H_2O/cerebrum H_2O ratio of .922 ± .003, while thirteen morphinized rats gave an average ratio of .939 ± .007.

TABLE

Condition	Duration	Average Medulla H_2O / Cerebrum H_2O	
		Rats (No.)	Rabbits (No.)
Anesthesia:			
Morphine sulfate	½–2½ hrs.	(13) .939 ± .007*	
Amytal	½–2½ hrs.	(5) .931	
Ether	½ hr.	(1) .936	(2) .933
Excitement:			
Ether	½ hr.	(1) .928	(2) .920
Muscular activity	½ hr.	(1) .924	
Controls (normal)		(15) .922 ± .003*	(3) .926

* Standard deviation of the average.

The above findings (which we plan to report more completely in *The American Journal of Physiology*) are entirely consistent with the conception that anesthesia in mammals is associated with the dehydration of nerve cell bodies. It is conceivable that early in narcosis the colloidal condition of the cells is altered in such a way as to extrude water (*cf.* Claude Bernard's semi-coagulation theory[6] or Hirschfelder's[7] demonstration of lessened lipoid dispersion).

Dehydration of the cerebrum is the rule, at least in rats. The extra water taken on by the medulla not only may be located entirely outside of the nerve cells but may even be derived from the nerve cells of both medulla and cerebrum. The interfibrillar spaces may well serve as a temporary storehouse for water during readjustments of brain pressure and the like. At all events our results indicate that the first accompaniment of brain narcosis is a temporary storage of water in the medulla, partly at the expense of the cerebrum.

H. G. BARBOUR

UNIVERSITY OF LOUISVILLE

METALLIZED FOOD IN THE REGENERATION OF HEMOGLOBIN IN RAT AND MAN

To eliminate the acidity of salt solutions used in the regeneration of hemoglobin in animals made anemic by deficient diets, Fe, Co, Mn and Cu were dissolved directly in milk while in the ice box.[1,2,3] After 12 hours half the milk was used after being shaken, and the balance was shaken and used 12 hours later. The metals were washed and placed in fresh milk for the next day and so on. In this way enough of the metals dissolve in milk to supply the requirements for rapid hemoglobin regeneration in rat and man, as seen below.

On April 22, 1929, two dozen young white rats, reduced to 75 per cent. hemoglobin by feeding on pure raw milk, were equally divided in two identical cages, A and B, Fig. 1, and each rat was then fed

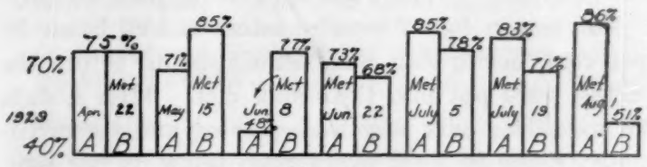


FIG. 1

50 cc of raw milk per day, free from metallic contact in its production and storage.[4] Into the 600 cc of milk for group B 181 gms of Fe, Co, Mn and Cu in alloy form were placed each day for the two feedings. A was the first and B the latter control. All hemoglobin is reported in percentage (Newcomer). The second and third graphs of Fig. 1 show the percentage *differences* after three and six weeks, being respectively 14 per cent. and 29 per cent. on May 15 and June 8. On June 8 the alloys were transferred from the milk for B to that for A. In 14 days group A average hemoglobin had risen from 48 per cent. to 73 per cent., while that of B had fallen from 77 per cent. to 68 per cent. as per the fourth graph. Progressive, average percentage differences increased as seen in the fifth, sixth and last graphs, when on August 1, 6 per cent. beyond a complete reversal appeared in average per cent. hemoglobin of the two groups. Tangents drawn to A and B of the third group and to B and A of the last group meet almost at right angles. Note that B on May 15 equals A on August 1, both with metals. Group B shows evidence of some metal retention by a very gradual decline in hemoglobin during 8 weeks. Fig. 1 shows remarkable hemoglobin control by a metallized diet.

In order to compare the hemoglobin regenerative effects of direct metallization with salt effects, the tests of Fig. 2 were made. The average hemoglobin of the rats studied in the 7 cages of Fig. 2 had dropped on a pure milk diet to 38 per cent., and all

[6] The current work of Bancroft and Richter (Proc. Nat. Acad. Sci., 16: 573, 1930., and *J. Phys. Chem.*, January, 1931) contributes striking evidence that narcotics produce a reversible semi-coagulation.

[7] A. D. Hirschfelder, *J. Pharmacol. and Exper. Therap.*, 37: 399, 1929.

[1] Clarice M. Burns, *Biochem. Jnl.*, 32: 5, 860.

[2] Elvehjem and Hart, *J. Biolog. Chem.*, 84: 131, 1929.

[3] Waddell and Steenbock, *J. Biolog. Chem.*, 84: 115, 1929.

[4] Lewis, Weischelbaum and McGhee, *Proc. Soc. Exp. Biol. and Med.*, 27: 329, 1930.

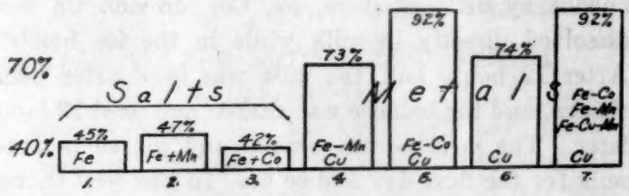


FIG. 2

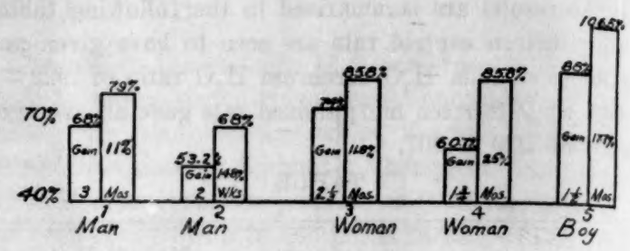


FIG. 3

were remarkably close to the horizontal line in the figure, when, on July 23, 1929, the indicated salts were added to the milk of the first three and the noted metals to the other groups, in weights seen in the table. The average rise in hemoglobin per cent. in each cage of 6 or 8 rats during 7 weeks is seen in the 7 graphs. Graph 6 shows effects of pure Cu only.

The rats in cage 7 were comatose and all below 38 per cent. hemoglobin with little appetite before the metals were put into their milk diet. After 4 days on metallized milk they were playing and ate ravenously, rising in eight weeks from below 38 per cent. hemoglobin to 92 per cent.

THE WEIGHTS OF SALTS FED PER RAT PER DAY IN FIG. 2

Cage	No. 1	No. 2	No. 3
	0.5 mg Fe as $FeCl_3$	0.1 mg Fe, 0.1 " Mn as chloride	0.1 mg Fe, 0.1 " Co as chloride

THE WEIGHTS OF COPPER AND ALLOYS PER RAT PER DAY IN FIG. 2

Cage	No. 4	No. 5	No. 6	No. 7
	Fe–Mn, 3.24; Copper, 0.31 mgs	Fe–Co, 0.135; Copper, .306 mgs	Copper .306 mgs	Fe–Co, 0.16; Fe–Mn, 3.04; Fe–Mn–Cu, .384 Copper, 0.27 mgs

These weights are cage averages. The sheet Cu is free from Fe, Al, Mg, Ni, Zn, Li, and has only traces of Co and Mn, respectively 10 parts and 1 part per million.

Copper alone is quite effective, but more so with other metals, suggesting that mutual influences probably exist when several metals function together, which may fail when they are separate.

After using metallized milk himself for eight months to determine possible pathological results, the writer secured the cooperation of physicians and executives in three local cotton mills and tests were made of the effects of metallized milk on a number of employees who had secondary anemia. Each person was examined after using a directed diet for two weeks including sweet milk, the percentage of hemoglobin being specially noted. Results typical of 50 cases are shown in Fig. 3, with a record of the hemoglobin percentage gain of each and the time involved.

The ages of the two men, two women and one boy, in order, are 59, 28, 49, 28 and 16 years. No change in color, odor or taste occurs if the immersed metals are pure. The man of graph 2, Fig. 3, ingested 0.5 mg of copper per day, and approximately 0.7 mg of iron. Tests of the duration of these effects are being made.

CONCLUSIONS

(1) Metals dissolve enough in milk to supply the requirements for rapid regeneration of hemoglobin in rat and man.

(2) Copper alone is effective but less so than when accompanied by other metals, especially iron.

(2) Much less mortality occurs among rats fed on metallized milk than when salts of the metals are used in anemia tests.

(4) These metals produce no odor, color, taste or other observed change in milk with the quantities used unless they are exposed to air and milk.

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